VSL

National Metrology Institute

IT4PQ

Instrument Transformers for Power Quality

IT4PQ WP1: Accuracy and uncertainty limits of instrument transformers for PQ measurements

Stakeholder workshop

09/02/2022

Helko van den Brom, VSL

INRIM, CMI, LNE, PTB, TUBITAK, RSE, SUN, TUD, UNIBO

Accuracy and uncertainty limits of ITs for PQ measurements

MV grid — Instrument transformer — PQ analyzer

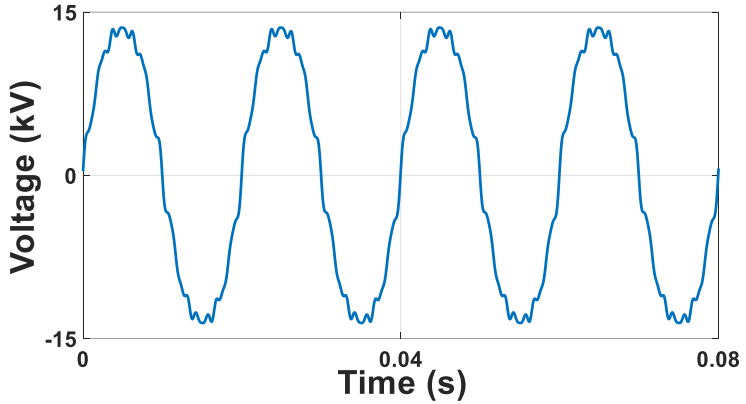
PQ limits:
IEC 61000
EN 50160
…

???

Requirements:
61000-4-30
60255-118-1
…

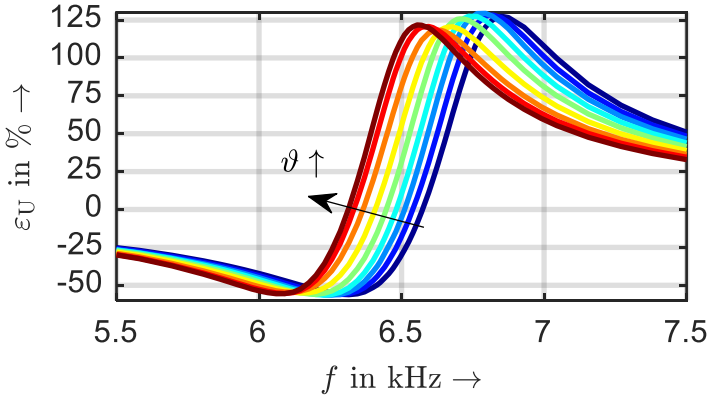
WP1 – Accuracy and uncertainty limits of instrument transformers

1. Selection of PQ phenomena and rated test conditions
   - Identify relevant PQ phenomena
   - Define relevant test conditions
   - Select relevant influence factors
   - Consider various categories of ITs
     (inductive, LPIT, combined sensors, analogue or digital output)



2. Definition of Performance Indices and measurement methods
   - Define PQ performance indices and related measurement methods
   - Consider stationary, dynamic, short and long-time variation and transient phenomena
   - Adapt PQ existing measurement methods

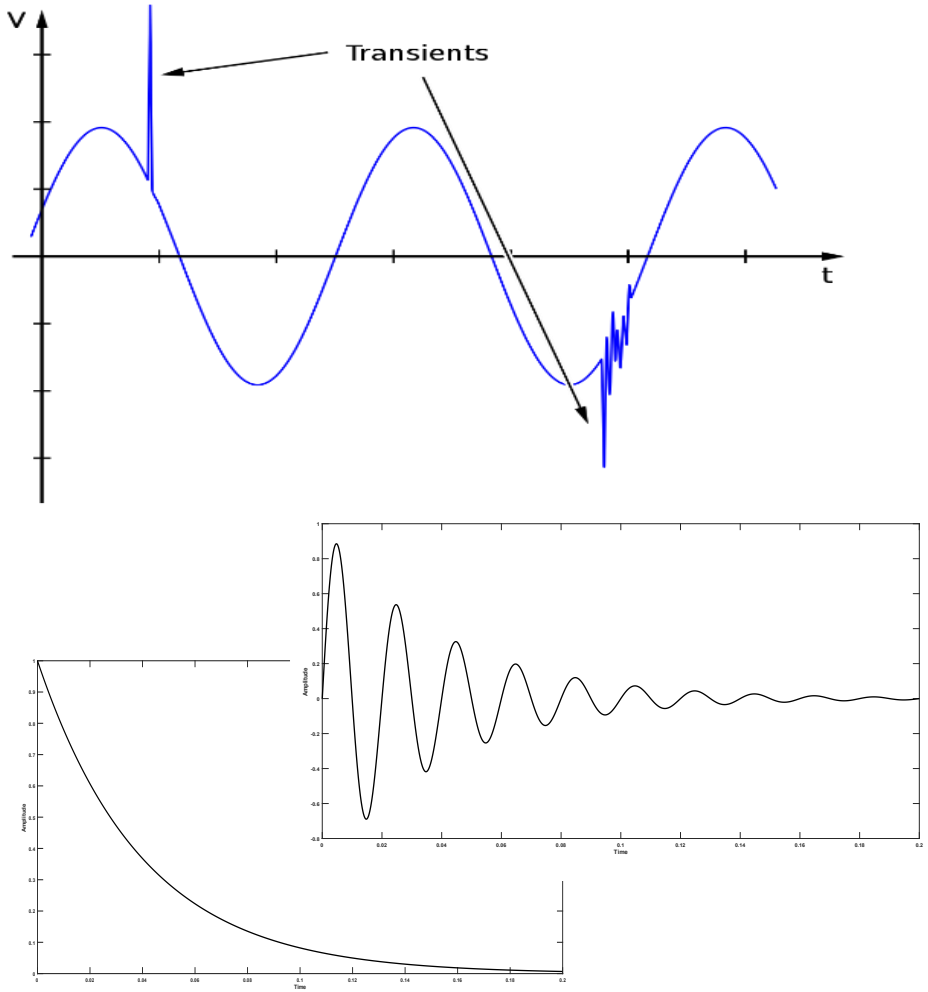
3. Definition of accuracy and uncertainty limits
   - Define the accuracy of ITs when used for PQ measurements
   - Define a “synthetic” performance index
   - Propose a "PQ Accuracy Class“ for ITs

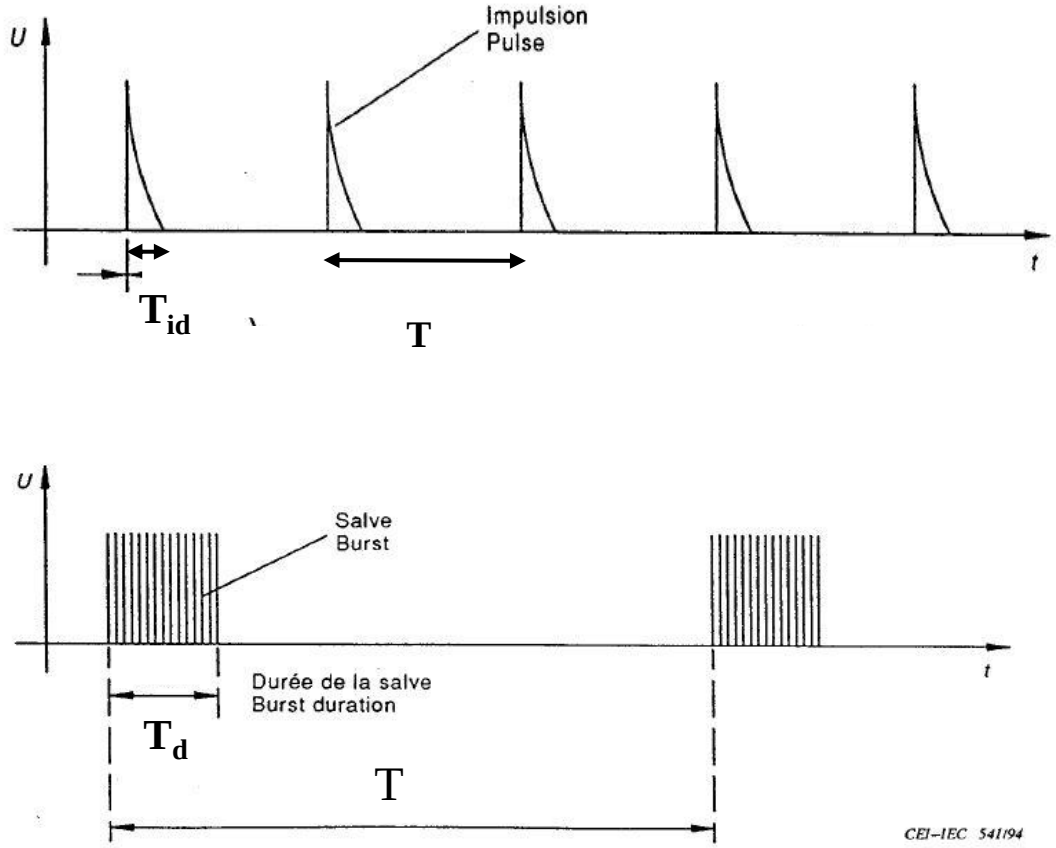


Selection of PQ parameters

Parameter	Remark	Select
Voltage stability	Is in the present standards already	No
Frequency stability	Frequency variations up to 15 % Frequency changes / phase jumps for ROCOF	Yes
Frequency linearity	Sweeping up to 9 kHz or 20 kHz to determine linearity, relevant for harmonic/interharmonic testing	Yes
Harmonics, inter- / sub-harmonics	How many, which amplitudes, which phase, up to which order? Single or combination, how to combine (e.g., highly peaked waveforms)?	Yes
Dips and swells (and interruptions	Not expected to add anything beyond voltage stability testing	No*
Rapid voltage changes	covered by voltage variation and transients	No
Flicker	Include flicker in interharmonics tests and modulations test	No
Modulations	Modulation of mains signal	Yes
Transients	Transient phenomena, e.g., burst of transients	Yes
Pulsed current signals	As disturbing electricity meters – covered by transient definitions	No

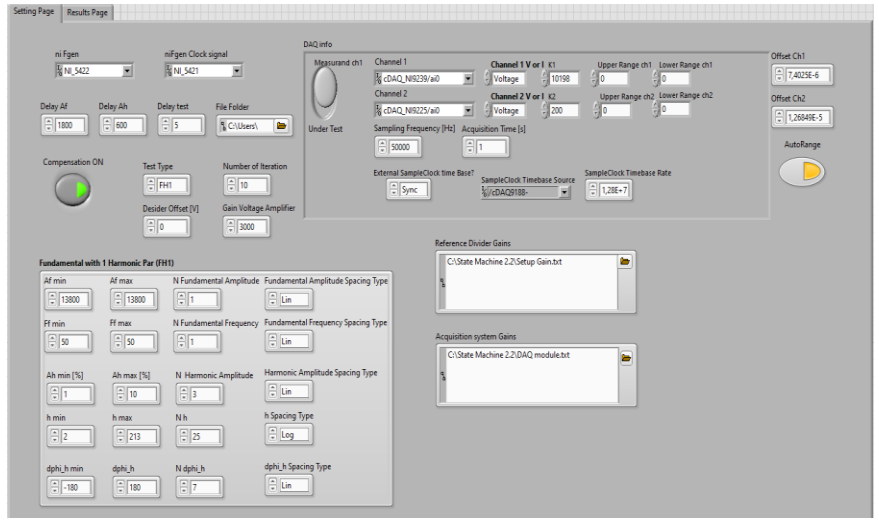
Transients up to 9 kHz (20 kHz)





PQ phenomena		Inductive ITs		LPITs			
				Analog output		Digital output	
		VT	CT	VT	CT	VT	CT
Voltage and current deviation		From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current
Frequency deviation		+/- 15 % of rated frequency (isolated systems)					
Harmonic and interharmonic		At least the rated voltage/current amplitude for fundamental component See Table 4.3.2 – 4.3.3 for spectral component					
		2-tones waveforms (fundamental tone at rated frequency with 1 spectral component from DC up to 9 kHz, including phase variation from 0 up to 2π rad)					
		Multi-tones waveforms (fundamental tone at rated frequency with spectral components from DC up to 9 kHz, including phase variation from 0 up to 2π rad)					
Dips (for verification)		10 % - 90 % of rated amplitude at point of wave from 0° up to 270° with 45° step and ±90° change at the beginning and the end of cycle					
Swells (for verification)		110 % - 150 % of rated amplitude at point of wave from 0° up to 270° with 45° step and ±90° change at the beginning and the end of cycle					
Interruption (for verification)		5% of rated amplitude at point of wave-interruption and restoration from 0° up to 270° with 45° step					
Response time		From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current
Transient overvoltage	Amplitude	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current	From 5% up to 200% of amplitude rated voltage	From 1% up to 200% of amplitude rated current
	Time duration	See Table 4.6.2					
Modulation	Amplitude	Frequency modulating from 0.1Hz up to 5Hz – Kx = 0.1					
	Phase	Frequency modulating from 0.1Hz up to 5Hz – Ka = 0.1 rad					
Frequency ramp		Ramp rate (Rf) ±1Hz/s starting from -5Hz up to +5Hz of rated frequency					
Burden		From 0% up to 100% for rated burden	From 25% up to 120% for rated burden	From 0% up to 100% for rated burden of VT; From 25% up to 100% for rated burden of CT		Not applicable	

Numeric generation of PQ waveforms



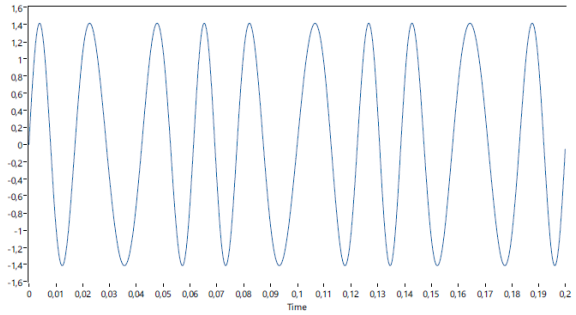


Figure 4-9 Phase modulation (Amplitude 1V, 50 Hz fundamental, 5 Hz modulating, 0.1 PM factor)

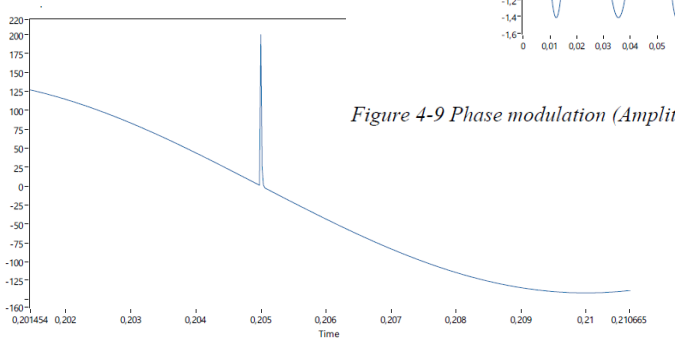


Figure 4-4 Single pulse Imulsive Transient (210V pk, 0.0005s rise time, 0.001s down time)

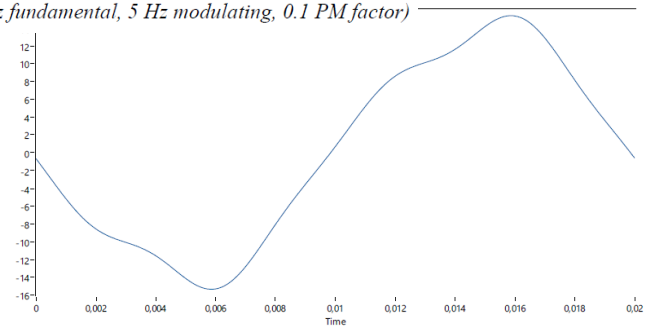
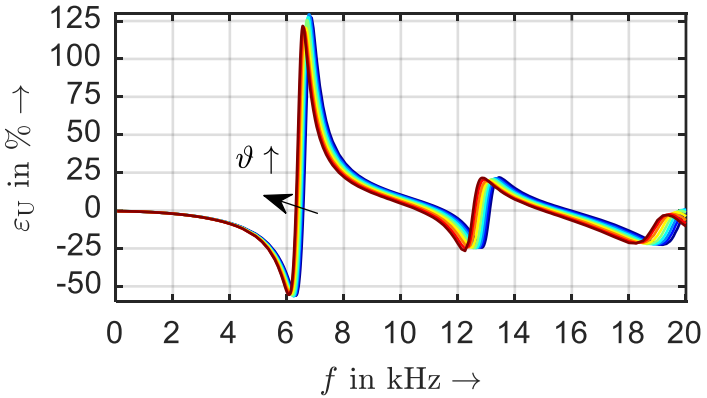
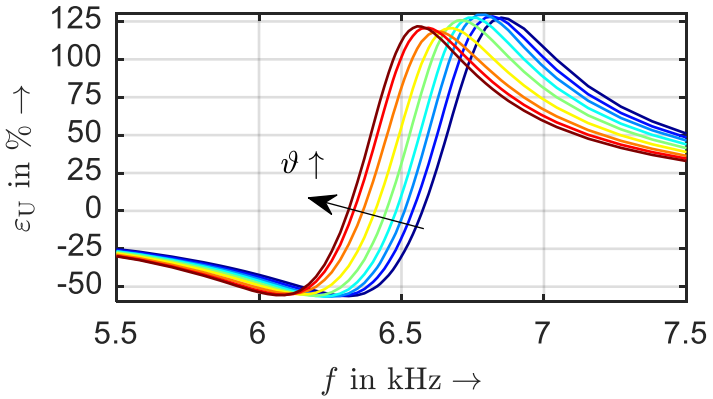


Figure 4-3 Harmonic distortion (3th order with 10% amplitude and 5th order with 5% amplitude)

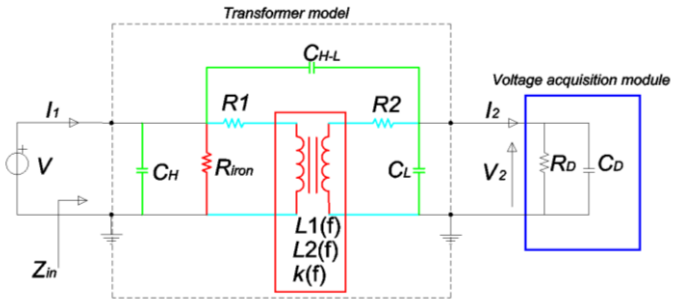
Identification of influence factors – long list

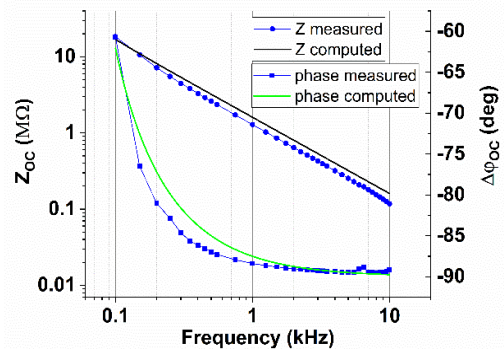
Influence quantities	Impact of the influence quantities					
	Type of voltage sensors			Type of current sensors		
	Capacitive	Resistive	Inductive (VT)	Resistive	Rogowski	Inductive (CT)
Temperature	High	High	Very Low	High	Medium	Very Low
Burden	Very High	Very High	Low	Very High	Low	Low
Proximity and positioning	High	Medium	Very low	Medium	Medium	Medium
Vibration	?	?	?	?	?	?
Self heating	High	High	Low	Very High	Low	Low
Frequency linearity up to 9kHz	low	low	Very High	Low	Low	Very High
Voltage (current) linearity	Low	low	Very High	Medium	low	Very High
Long term instability	High	High	Very low	High	low	Very low
Magnetic field	Low	Low	Medium	Low	Very high	High
Influence of overvoltages (overcurrents)	Low	Low	Very High	High	Medium	Very High
Short-circuited secondary	Very Low	Very Low	Very high	Very Low	Very Low	Very Low
Open secondary	Very Low	Very Low	Very Low	Very Low	Very Low	Very high
Influence of current on voltage	Low	Low	Low	X	X	X
Influence of voltage on current	X	X	X	Low	Low	Low

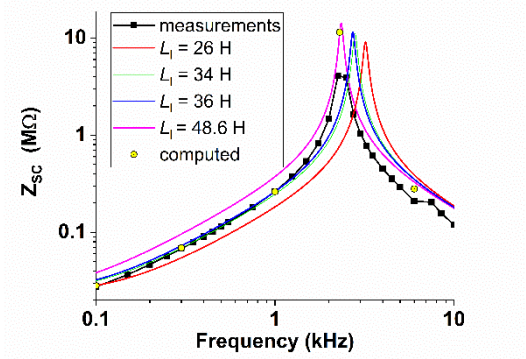




Simulations and experiments: effects of influence factors of VTs







Towards the Evaluation of Instrument Transformers' Accuracy in Harmonic and Interharmonic Measurement

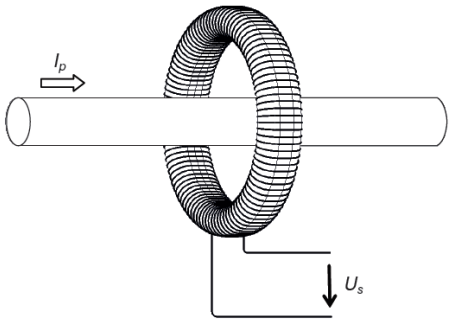
Gabriella Crotti
Italian National Metrology Institute, INRIM
Torino, Italy
g.crotti@inrim.it

Giovanni D'Avanzo
Dept. of Engineering
University of Campania "Luigi Vanvitelli"
Aversa (CE), Italy
giovanni.davanzo@unicampania.it

Palma S. Letizia
Politecnico di Torino
Italian National Metrology Institute, INRIM
Torino, Italy
p.letizia@inrim.it

Mario Luiso
Dept. of Engineering
University of Campania "Luigi Vanvitelli"
Aversa (CE), Italy
mario.luiso@unicampania.it

Identification of significant influence factors



$$u_s(t) = M \frac{di_p(t)}{dt}$$

	Voltage sensor			Current sensor		
Influence quantity	Capacitive	Resistive	Inductive	Resistive	Rogowski	Inductive
Temperature	High	High	Medium	High	Low	Medium
Burden	Very High	Very High	Medium	Very High	Very High / Low [1)]	Medium
Vibration	?	?	?	?	?	?
Amplitude of Voltage/ Current	Low	Low	High	Low [2)]	Low	High
Positioning	High	Medium	Low	Low	High	Low
Magnetic /Electric Field	High	Medium	Low	Low	High	Low

WP1 – Summary and future work

- Relevant PQ parameters selected
- Ranges defined based on literature and standards
- Different types of ITs considered
- Significant influence factors identified based on experience and initial testing
- Performance indices are under construction
- Accuracy limits need feedback from experiments (other WPs)
- **Feedback and support from stakeholders would be appreciated**

Thank you for your attention!